

# Heavy Ion Fusion: Issues/Challenges/Plans

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# There is much to be proud of in recent HIF progress

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▪ **The progress in current research is very gratifying-our investment in building three VNL experiments (HCX, NTX, STS) is starting to pay off (my morning talk). Exciting experimental opportunities remain for 04 and 05.**

**Outside the VNL, advances in chamber and target R&D support our long-held vision for heavy ion fusion energy:**

- **development of smooth and oscillating liquid jets and clearing experiments for thick liquid protected long-life chambers (UCB)**
- **a final focus magnet design for power plants that can last for 30 years without replacement (LLNL)**
- **hohlraum targets that can be economically mass produced (GA)**
- **HIF target designs and planned experiments that, if successful, could accept larger 5 mm radius focal spots (LLNL)**
- **rapid completion of the National Ignition Facility (LLNL)**

# HIF-VNL Issues / Challenges:

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1. There are important experiments using existing facilities to be completed in FY04-05. Our total labor (scientific and technical) is a large fraction of guidance funding. Staff reductions (1.2 scientist, 0.6 engineer, 2 technical) and delays of some 3-yr plan goals have already occurred as a result of 02 and 03 cuts. With guidance funding, allowances for experimental operation would shrink to near zero in FY05 without further staff reductions.
2. If DOE commits to an IBX Physics Validation Review (CD0) by April FY05, we will redirect staff and further focus experimental effort in FY04 and FY05 to support IBX-PVR needs. We would still require modest increments in FY04 (\$1.5 M) and FY05 (\$3M), or else we would have to stop experiments or delay the PVR to 06.
3. An early start on IBX, and restoration of effort on HIF chamber and target R&D, is essential for an HIF development schedule competitive with other fusion approaches (FESAC Fusion Development Path Report).

# HIF-VNL budgets have been eroding since FY00→major effect on operational support<sup>1</sup> for beam experiments

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	FY00	FY01	FY02	FY03**	FY04	% change (FY01-04)
Actual HIF-VNL budgets * (\$K)	11,440	10,560	10,288	10,035	10,100***	- 4.3%
Total OFES-IFE (\$K)	19,000	18,000	17,600	17,000	13,200	- 27%
Total OFES fusion (\$M as spent)	238	242	241	250	257.3	+ 6.3 %

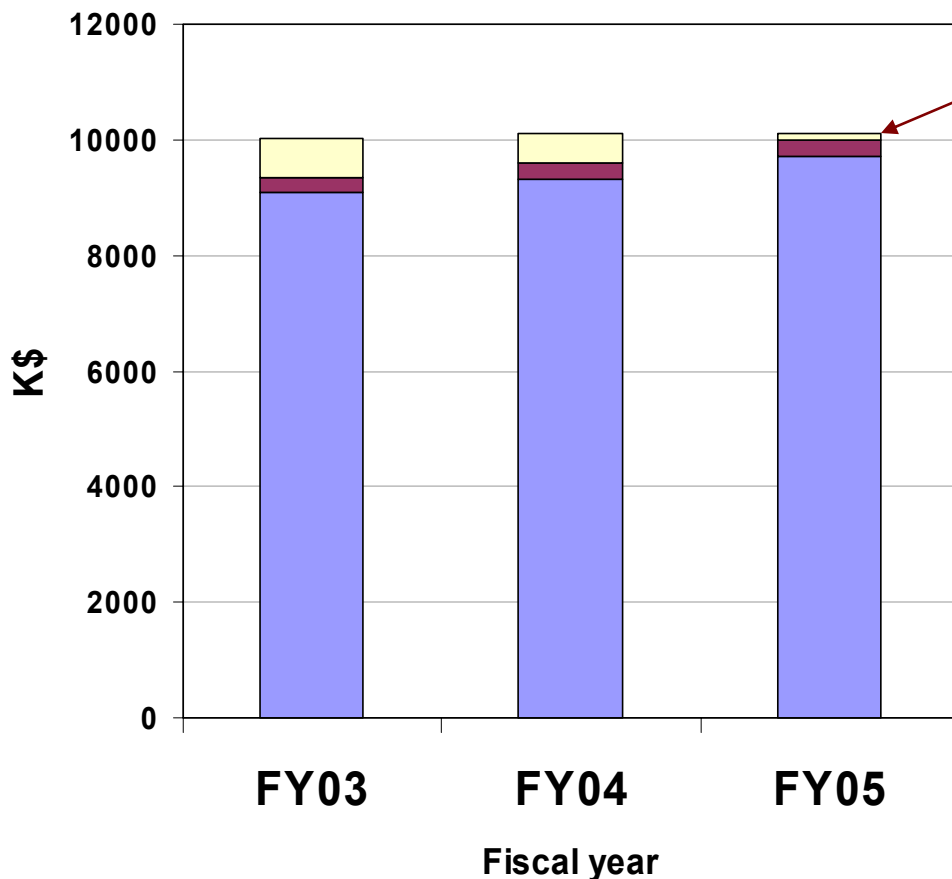
\*Totals for HIF-VNL (LBNL, LLNL, PPPL)

\*\* Does not assume any recission

\*\*\*FY04 Presidents Request

1- Procurements, lab space fees,  
electricity, other consumables

**With guidance funding, we must be more selective in experiments for FY04 and 05, and we must also consider 1-2 FTE further staff reduction in FY05.**



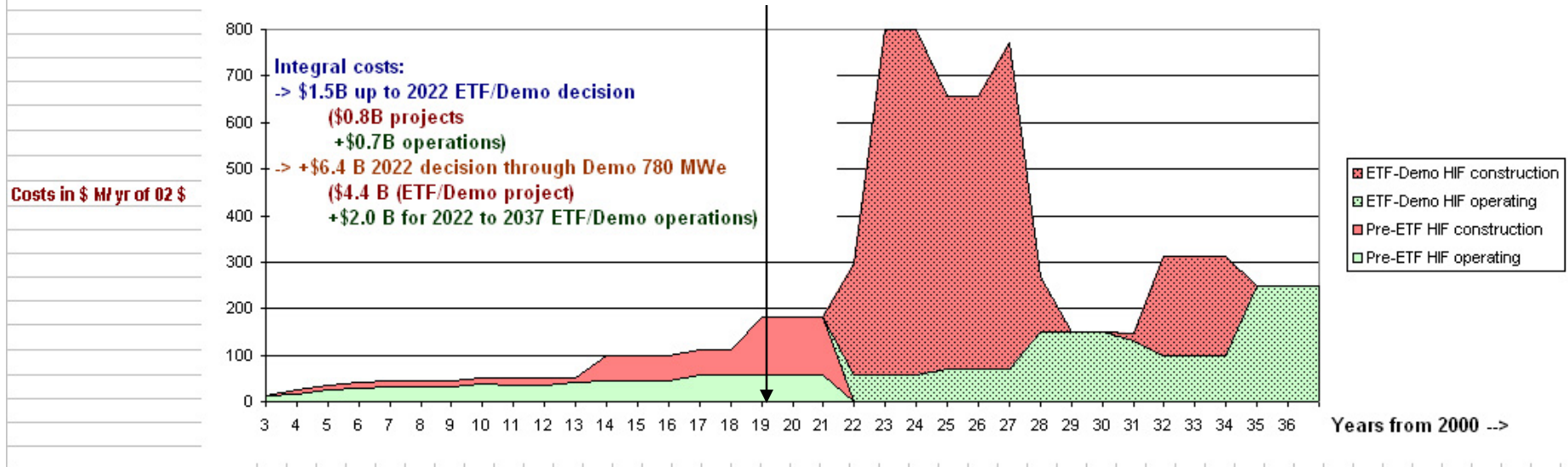
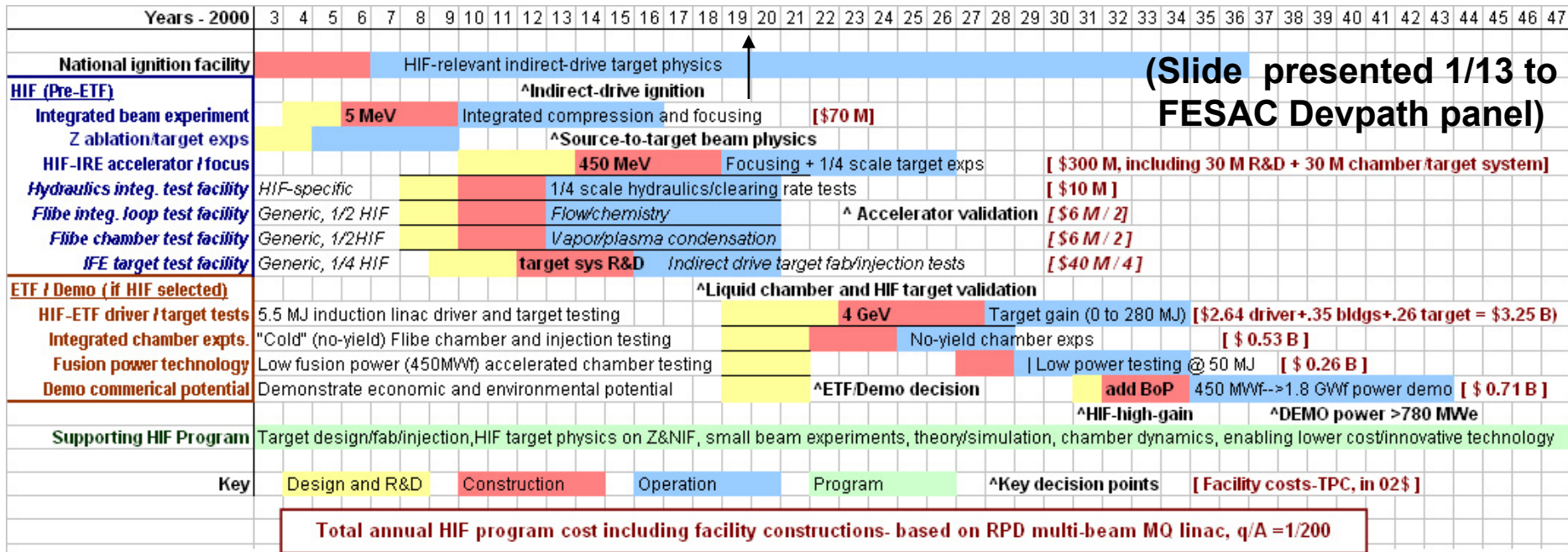
**We must rebalance the program in FY05 to preserve experimental capability**

■ Procurements for exps  
■ Lab space/electricity for exps  
■ All labor+office costs

**(Electricity is about 25% as much as lab space taxes)**

*(Any involuntary staff reductions in FY05 will require HIF-VNL oversight board approval)*

# A timely IBX is critical to HIF being a credible fusion option



## **FY04 and FY05 Plans**

- **10% Decrement case**
- **Guidance case**
- **Full request case**
- **Minimum increment case**

## **10% Decrement Case (FY05=0.9x FY04 Presidents Budget.**

▪FY05 =  $0.9 \times 10,100 = 9090$  K exactly equals present staff + office space costs, ~ 600 K below staff + office costs escalated to FY05

→No experiments without significant staff reductions

→would force 15 % staff reductions for the VNL

→may trigger a RIF in Accelerator Fusion Research Division that includes HIF at LBNL. At LLNL's Fusion Energy program, staff would have to migrate to Homeland Security or NIF programs

→we would postpone IBX effort, and seek ways to modify existing facilities to do some limited-integrated beam physics experiments.



# Guidance case

# Summary of the HIF-VNL Field Work Proposal for FY04-05 Guidance Budget Case

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Task Area	FY 04 (\$K)	FY 05 (\$K)	Comment
Theory & Experiments	9,618	9,318	Supports fewer important experiments, requires ~2 FTE staff reduction in 05
IBX Design	500	800	IBX PVR in FY06 only, no R&D
Total VNL	10,118*	10,118*	
LBNL	5173+390E	5173+390E	← E = Equipment \$
LLNL	3400	3400	
PPPL	1155	1155	← needs 60K for MRC contract

\*President's budget for FY04 for the tri-lab HIF-VNL total

**Assuming no rescission of FY03 funding below 10,035 K, we are prepared to meet FY03 and 04 OFES performance targets for HIF (in FY2004 Congressional Budget, p 469)**

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**FY03: “Conduct beam transport analysis for full current beams in HCX to provide a database for end-to-end beam simulations”**

**FY04 “Evaluate the effects of stray electrons on heavy-ion beam instabilities by comparing results from the high current experiment (HCX) with calculations of beam transport through HCX”**

# **FY04 and 05 milestones for guidance funding are a subset of our FY02 3-yr plan-highest priority**

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## **MILESTONES FOR FY04 (Guidance level)**

- 08/04** Complete report on final focus magnetic transport, and neutralization with plasma plug and volumetric plasma
- 09/04** Complete phase-1 multi-beamlet merging experiment at scaled voltage
- 09/04** Experimentally determine secondary electron, ion and gas effects in magnetic quadrupole experiments, including consequences of fields generated by induction cores
- 09/04** Using new computational tools, simulate the dynamics of stray electrons in induction accelerator, and the effects of such electrons on the beams. Begin assessment of selected methods to inhibit electron buildup

## **MILESTONES FOR FY05** *(These FY05 goals would be impacted by ~ 2 FTE reduction in VNL staff to fund experimental operations. Requires approval by VNL Oversight Board)*

- 03/05** Complete experiments on gas effects in neutralized transport
- 06/05** Experimentally determine mechanisms and rate of beam halo growth in the HCX system.
- 09/05** Complete phase 2 multi-beamlet merging experiment at full gradient
- 09/05** Carry out detailed integrated simulations from source to target of one operating scenario of the IBX as developed in the physics design.

# Full FWP request case

# Summary of the HIF-VNL Field Work Proposal for FY04-05

## Full FWP Request Budget Case

Task Area	FY 04 (\$K)	FY 05 (\$K)	Comment
Theory & Experiments	11,240	11,950	Strengthen HIF experimental operations (10%)
IBX-Related Work	5,550	7,300	IBX PVR in FY05, CDR in FY06, inc. IBX R&D
Total VNL	16,790	19,250	← E = Equipment \$
LBNL	6870+2000E	8060+2000E	
LLNL	5670	6395	
PPPL	2250	2795	

# **The full request case (FWP) for the HIF-VNL expedites IBX by strengthening supporting experiments and physics design and enabling IBX technology**

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## **Milestones for FY04**

- Neutralized focusing (NTX) -deliverables same as guidance case
- Injector (STS-500/100)- deliverables same as guidance case
- Extend HCX to 30 electrostatic quads (4.5 oscillation periods)
- Theory/simulation: support experiments and IBX design
- **Enabling accelerator technology for IBX (accelerator module, short-pulse injector R&D, diagnostics and control tests)** ←enables CD1 one year beyond CD0

## **Milestones for FY05**

- Neutralized focusing (NTX) -deliverables same as guidance case
- Injector (STS-500/100)- deliverables same as guidance case
- HCX-characterize halo growth, phase space evolution with 30 quads
- Theory/simulation: support experiments and IBX design
- **Enabling accelerator technology for IBX (continue accelerator module, short-pulse injector R&D, diagnostics and control tests, and begin CDR work)**

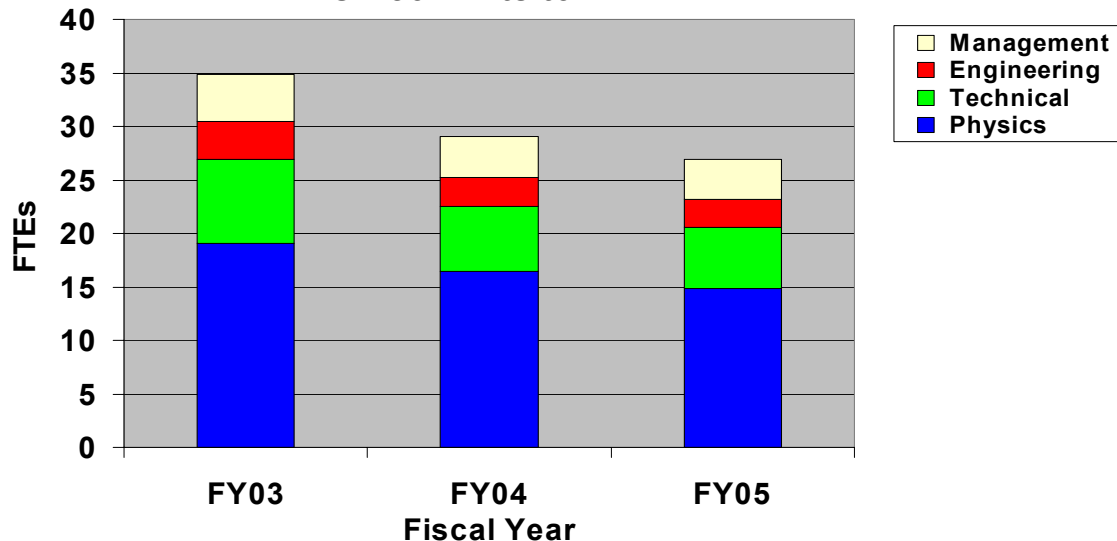
# Minimum increment case for IBX-PVR in FY05



## Minimum increment case, assuming IBX PVR in 05

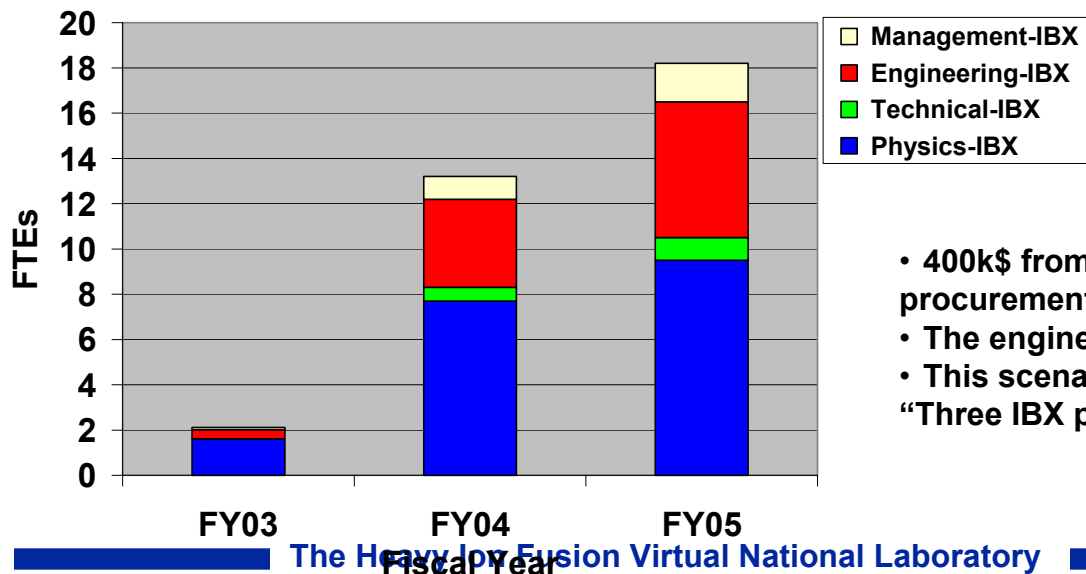
<b>Task Area</b>	<b>FY 04 (\$K)</b> <b><math>\Delta = \\$1.5 \text{ M}</math></b>	<b>FY 05 (\$K)</b> <b><math>\Delta = \\$3 \text{ M}</math></b>	<b>Comment</b>
<b>Supporting Theory &amp; Experiments</b>	<b>9618</b>	<b>9718</b>	<b>Restores operation support to FY04 levels for experiments</b>
<b>IBX Design</b>	<b>2000</b>	<b>3400</b>	<b>IBX PVR in FY05, with minimal R&amp;D (small scale)</b>
<b>Total VNL</b>	<b>11,618</b>	<b>13,118</b>	

## Experiments & Theory (FTEs) if DOE commits to IBX-PVR



**An April 05 IBX-PVR requires both key 04 and 05 experimental data and a ramp up in IBX design efforts, (minimum increments = \$1.5M in FY04, \$3M in FY05). Delays most IBX technology development compared to the full request case.**

## Proposed IBX Design Effort (FTEs) if DOE commits to IBX-PVR



IBX Staff	FY03	FY04	FY05
VNL lab transfers	0.14	5.45	9.25
Redirected VNL	1.97	7.75	8.95
<b>TOTAL IBX:</b>	<b>2.11</b>	<b>13.20</b>	<b>18.20</b>

- 400k\$ from the 3M\$ increment in FY05 goes for procurements to support experiments needed for IBX
- The engineering supports a CDR in FY07
- This scenario corresponds to the last scenario (scenario 3) "Three IBX project scenarios with FY05 PVR"

# **Deliverables for the minimum increment case**

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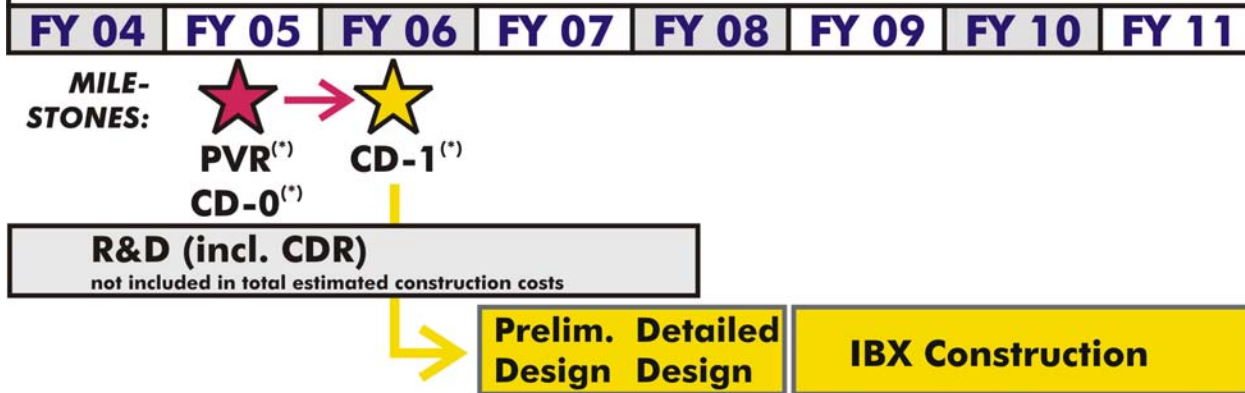
## **Milestones for FY04**

- **Supporting theory/experiments: deliverables same as for 04 guidance case**
- **Enabling IBX accelerator technology: evaluate SBIR induction module and short pulse injector test data on existing facilities for IBX design needs.**
- **Longitudinal physics design for IBX-injector through drift compression**
- **Dynamic vacuum calculations and improved cost estimates for IBX**

## **Milestones for FY05**

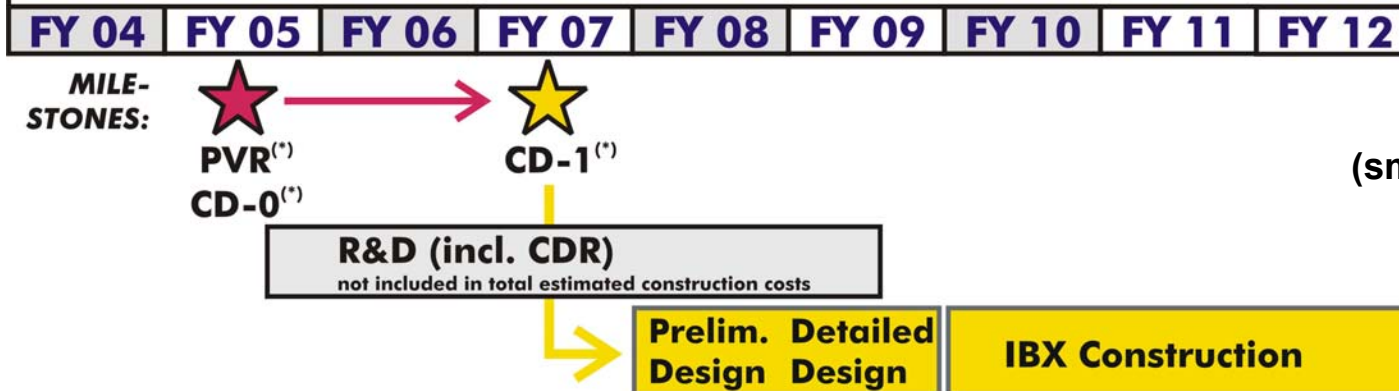
- **Supporting theory/experiments: increase experimental support to achieve deliverables listed for 05 guidance case**
- **Enabling IBX accelerator technology: continue tests of SBIR induction module and short pulse injectors. Evaluate prototype IBX superconducting magnet with cryo-pumps test data on existing facilities for IBX design needs.**
- **Support for IBX PVR in April FY05, begin engineering for CDR**

## FULL FUNDING CASE



Full R&D in FY04  
 PVR in FY05  
 CDR in FY06  
 Project-Construction  
 Start FY09

## MINIMUM INCREMENT CASE



PVR in FY05  
 Less R&D in FY06  
 (increases project risk)  
 (small-scale R&D in FY05)  
 CDR delayed to FY07  
 Project-Construction  
 Start FY10

(\*) PVR ... PHYSICS VALIDATION REVIEW  
 CD-0 ... MISSION NEED JUSTIFICATION  
 CD-1 ... CONCEPTUAL DESIGN REVIEW

# Heavy Ion Fusion-PPPL Request Case

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PPPL Funding Request for FY2004 and FY2005 in VNL Task Areas

	FY 2004-05	FY2004	FY2005
Task Area	Guidance	Increment	Increment
1	\$643K	---	---
2	\$220K	\$50K	\$50K
3	\$100K	\$120K	\$120K
4		\$800K	\$1,500K
5	\$180K*	\$60K*	\$60K*
Total	\$1,143K*	\$1,030K*	\$1,730K*

\*May need small 60K adjustments by fin plan transfers pending review

1. Theory and modeling
2. RF plasma source and neutralized transport experiments
3. Multi-electron loss events and negative-ion neutral beams.
4. Engineering design and test activities (supports IBX)
5. MRC subcontract / Chamber transport modeling.

# University of Maryland Electron Ring (UMER) Research Goals (through 2005)

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Multi-turn dynamics – *bunch capture and shaping*; beam end confinement using induction gaps.

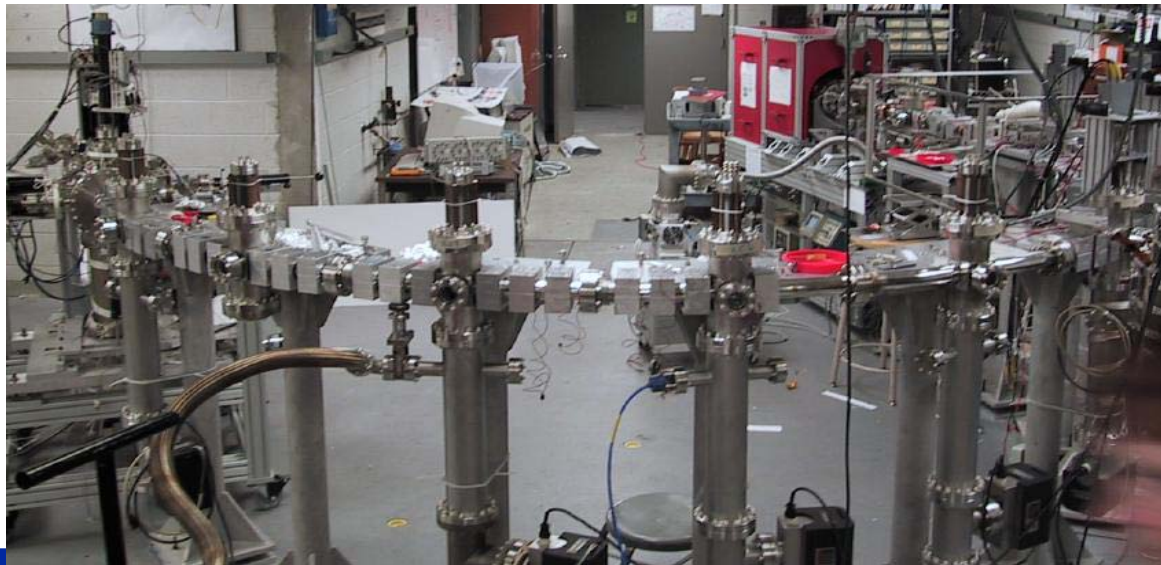
Energy Spread

Beam Dynamics Studies: Resonances, Halos, Anisotropy

Space Charge Waves: Transverse and Longitudinal

Generation of arbitrary perturbations using laser

Design Acceleration Phase (up to 50 keV)



←Photo of UMER  
Dec. 2002.

Completion  
expected late 2003

# Distribution of VNL effort towards IPPA 5 yr objectives

Across: 5-year objectives (from FESAC Knoxville IPPA Reports) <b>Down: HIF-VNL scientific issue</b>	6 . 1 Heavy Ion Beam Experiments and Supporting Accelerator Tech.	6.2 Integrated Ion Beam Modeling, Focusing and Transport	5.1 Beam Target Interaction and Coupling
<b>(1) beam brightness in heavy-ion sources</b>	<b>30%</b>		
<b>(2) dynamical phenomena in transport and acceleration</b>	<b>30%</b>		
<b>(3) non-linear processes in chamber propagation/focusing</b>		<b>5%</b>	<b>5%</b>
<b>(4) computational tools</b>		<b>25%</b>	<b>5%</b>